SEVEN publicações acadêmicas & HOME PUBLISHING BRAZIL

Analysis of mathematical modeling within the assessment of thermal comfort in the city, patos-PB

Crossref doi 10.56238/homeinternationalanais-121

Ana Paula Dutra Ferreira
UFERSA STUDENT – Caraúbas, RN, Brasil
E-mail: socorro080172@gmail.com

Maria do Socorro Medeiros de Souza
UFERSA STUDENT – Caraúbas, RN, Brasil
E-mail: socorro080172@gmail.com

João Luis Medeiros de Souza
IFRN STUDENT– Santa Cruz-RN, Brasil
E-mail: medeirosppar@gmail.com

João Luis Fernandes Medeiros de Souza
IFRN STUDENT– Santa Cruz-RN, Brasil
E-mail: medeirosppar@gmail.com

Kátia Alves Praxedes
EAJ/ UFRN STUDENT – Macaíba., RN, Brasil
E-mail: harasfms@gmail.com

Keywords: Climate, Temperature, Thermal sensation.

1 INTRODUCTION

The sensation of thermal comfort is associated with the rhythm of heat exchange between the human body and the environment, it occurs in different types of spaces and is provoked by several parameters that influence the temperature, such as buildings, climatic factors, and the presence of vegetation, which can make environments inappropriate or not to be (Carfan et al., 2010).

A concept that has been studied to classify thermal sensations that the body feels is the heat index. According to Santos et. al, (2015), this index is used in cases of locations with high temperatures and exposure to open spaces.

In cities, man has a mutual influence on the climate. The urban environment has been modified with the accelerated growth of cities through the urbanization process that was consolidated in the twentieth century, thus changing the structure of cities and especially the air temperature and increasing the thermal discomfort for the people who live in them. live.

Santos et al. (2011) highlighted that in tropical countries, as in the case of Brazil, the discussion about the well-being of citizens about thermal comfort is extremely important, especially in inland cities, where adequate urban planning can minimize "stress". thermal". Leal (2012) justified that the planning of urban forests, contemplating the creation of parks, woods, and street trees, are the most efficient measures to promote changes, mainly in the urban microclimate.

The Heat Index was a relationship created in 1979 by R. G. Steadman, which associates values of temperature and relative humidity of the air to determine an apparent temperature, representing the thermal sensation felt by the organism. The index is indicated for regions where temperatures are high, with the analyzed individual being in the shade and light wind conditions. (Santos et al., 2015).

Queiroga (2019) states that understanding thermal comfort can contribute to the quality of the population's health, influencing people's behavior and the planning of urban spaces.

On hot and humid days, the thermal sensation will provide more unpleasant situations for the human body, causing fatigue and another series of concerns for the population (Nóbrega and Lemos, 2011). The apparent temperature or heat index is quantified to obtain the feeling of comfort related to air temperature and relative humidity. This index results in an alert system for the population, showing the level of danger it can pose.

In this way, the analysis of the city's comfort can contribute to public health and corroborate with new public policies regarding urban tree-planting projects, based on environmental and urban planning. For such an understanding, some indices calculate how much the population can suffer from thermal discomfort, the main ones are Heat Index (CI), Thermal Discomfort Index (TDI), and Temperature and Humidity Index (ITU).

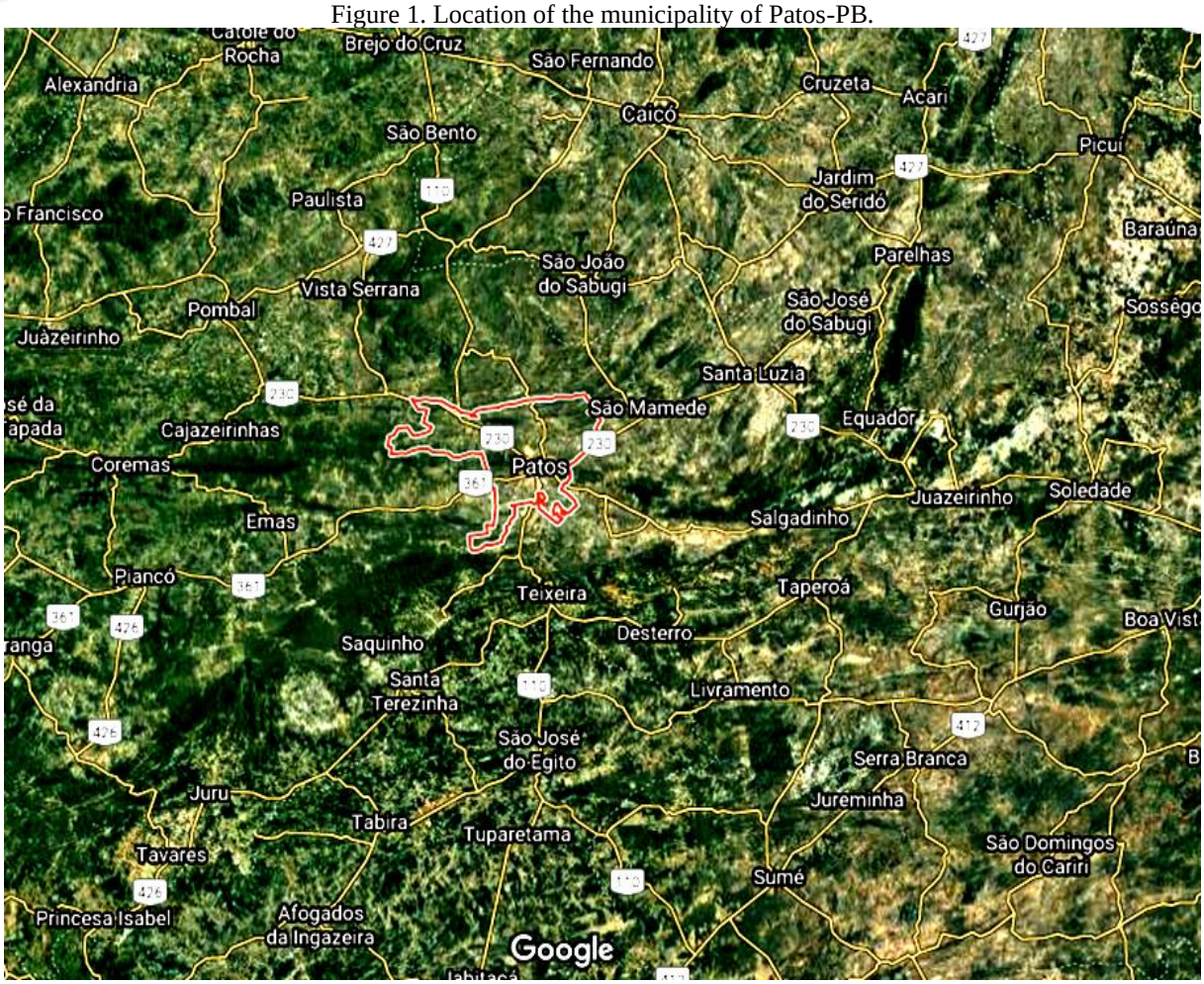
The objective of the present work was to analyze the thermal comfort indices in the city of Patos (PB) in the years 2017 to 2018 using historical data obtained from INMET.

2 METHODOLOGY

The study area in the municipality of Patos, Paraíba (Figure 1) is located in the Midwest region of the State of Paraíba, Mesoregion Sertão Paraibano and Microregion Patos, presenting a semi-arid, hot, and dry climate. It is inserted in the Piranhas River Basin, limited to the north with São José do Espinharas and São Mamede, east with São Mamede, Quixaba, and Cacimba de Areia, south with Cacimba de Areia, São José do Bonfim and Mãe d' Water, and west, with Malta and Santa Teresinha. (IBGE, 2019).

The population of the city of Patos is 107,605 people (IBGE, 2019), with a territorial unit area of 473,056km² (IBGE, 2018) and a per capita GDP of 15,882.57 R$ (IBGE, 2017).

Figure 1. Location of the municipality of Patos-PB.



In this study, historical data of temperatures and relative humidity from the automatic stations of the National Institute of Meteorology - INMET (Figure 2), through the Meteorological Data Bank for Teaching - BDMEP, for the years 2017 to 2018 were used. the time chosen for data collection at the station was 01/01/2017 and 12/31/2018, the station is in operation, with OMM identification: 82791, with (latitude: -7.01°; longitude: -37, 26°).

Figure 2. The meteorological station of Patos-PB.

Through historical data obtained, climatic variables such as air temperature and relative humidity were. With these data, CI, TDI, and THI were calculated.

Steadman's methodology (1979) was used to calculate the heat index (Equation 1). The formula is represented below, where IC is the Heat Index (°C), T is the maximum daily temperature, being the dry bulb temperature in (°C) and UR is the relative humidity in %.

Equation 1:

IC = -42,379+2,04901523T+10,14333127UR-0,22475541TUR-0, 00683783T2-
0,05481717UR2+0,0122874T2UR+0,00085282TUR2-0,00000199T2UR2……...…….....(1)

Table 1. Alert levels and possible physiological symptoms for people, according to the Heat Index, adapted from the National Weather Service Weather Forecast Office, NOAA. (1991).

Heat Index	Danger level	Heat syndrome
27 °C	Absence	Absence
27 - 32 °C	Attention	Fatigue
32 - 41 °C	Very careful	Cramps, heatstroke exhaustion from prolonged exposure.
41 - 54 °C	Danger	Cramps, sunstroke, and exhaustion are likely. Possibility of brain damage (stroke) for prolonged exposure.
IC > 54° C	Extreme danger	Sunstroke and eminent cerebrovascular accident (CVA).

Thom's methodology (1959) was used to calculate the Thermal Discomfort Index (Equation 2), in which the index is a function of maximum temperature and relative humidity. The formula shown below is where TDI is the thermal discomfort index (°C), T is the temperature in °C and UR is the relative humidity in %.

Equation 2:

IDT = T- (0,55- 0,0055UR). (T-14, 5) .....(2)

Based on the TDI reference values, it is possible to identify the level of discomfort according to Table 2.

Table 2. Level of Thermal Discomfort according to TDI.

IDT (°C)	Thermal Discomfort Level
IDT < 14,9 °C	Uncomfortable
15 - 19,9 °C	Comfortable
20 - 26,4	partial comfort
IDT > 26,5	Uncomfortable

Source: Silva et al. (2009).

The Temperature and Humidity Index (ITU) is used to quantify the “stress” in urban environments (BARBIRATO et al., 2007). The formula is represented by the equation below, where THI is the thermal discomfort index, where T is the temperature in °C and UR is the relative humidity in %:

The reference level for thermal comfort according to THI values can be seen in table 3.

Equation 3:

$$ITU = 0.8T_{ar} + \frac{U_R T_{ar}}{500} \quad \text{.....(3)}$$

Table 3. Level of thermal comfort according to THI.

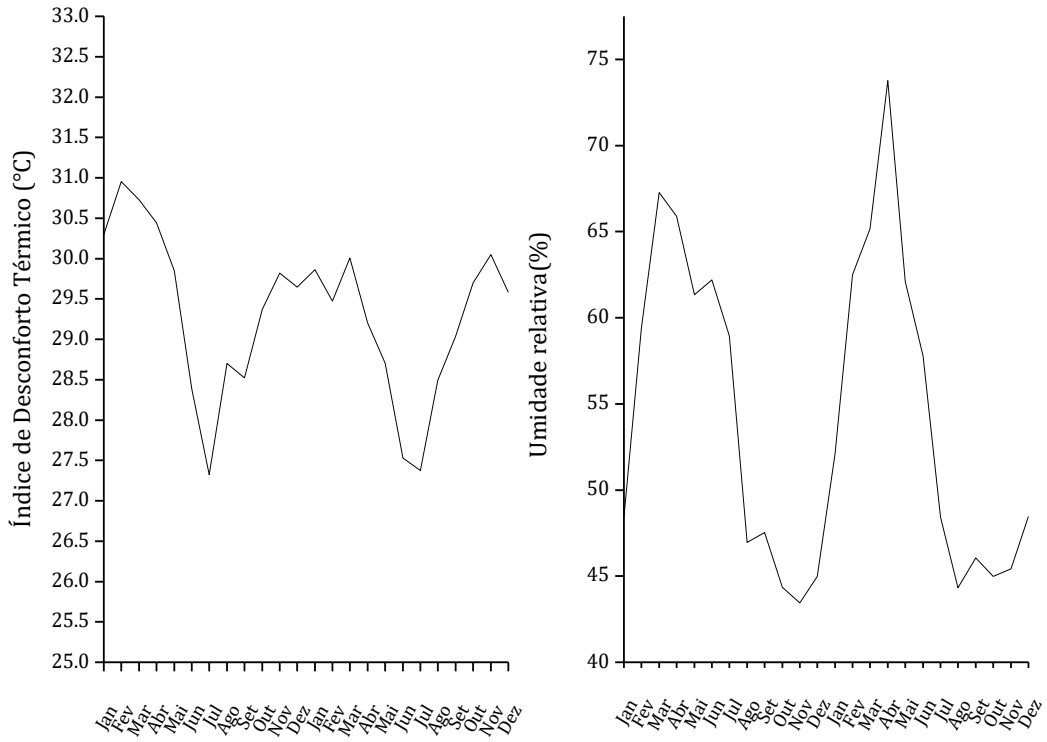
Comfort level	**ITU**
Comfortable	42<ITU<24
Slightly uncomfortable	24<ITU<26
Extremely uncomfortable	ITU>26

After obtaining the necessary climatological variables for the calculations, the results obtained were tabulated and calculated using the Excel 2016 software, where graphs were made for better visualization of the behavior of the variables and indices related to human thermal comfort.

3 CONCLUSION

From the results it was possible to make the graphs, to evaluate the variations of maximum temperature, relative humidity, precipitation, Thermal discomfort index Temperature and humidity index, and Heat index during the period for the study time interval in the months of 2017 to 2018 of observations, as the stations have a vast amount of information, it allows us to analyze with more depth.

Graph 1. Values of the Thermal Discomfort Index (RTI) and Mean Relative Humidity (URM) of the monthly averages for the years 2017 to 2018 in the city of Patos, Paraíba.



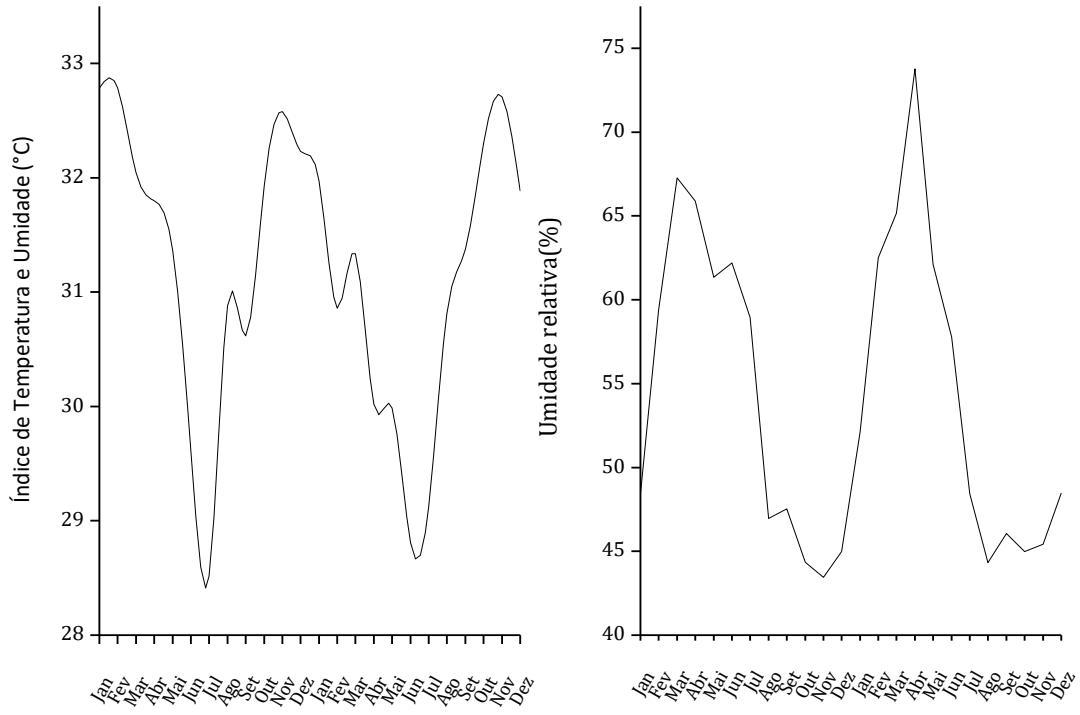
Analyzing, the highest TDI values in 2017 (Graph 1) were in February and September, with 32.43 and 31.64°C, values considered uncomfortable (Chart 2). In 2018, the highest TDI values were in November and December, with 31.29 and 31.25 °C, respectively. Values considered uncomfortable when (Chart 2).

For the lowest TDI values considered in 2017, they were in July and August, with 28.03 and 28.89°C (Table 2). In 2018, the TDI months below July and August were the lowest values were 29.25 and 29.07°C, respectively. All are considered uncomfortable as shown in Table 2.

The city of Patos-PB had the highest URM index of 73.77% in April 2018 (Graph 1), it is observed that the lowest value under study was 43.45% in November 2017.

According to Santos et. al, (2015), these are conditions of high temperatures, which can lead to an increase in the body's cellular metabolism, as well as the production of heat, so that the body begins to show symptoms such as intense sweating, changes in breathing and heart rate.

Graph 2. Values of the Temperature and Humidity Index (ITU) and Average Relative Humidity (URM) of the monthly averages of the years 2017 to 2018 in the city of Patos, Paraíba.

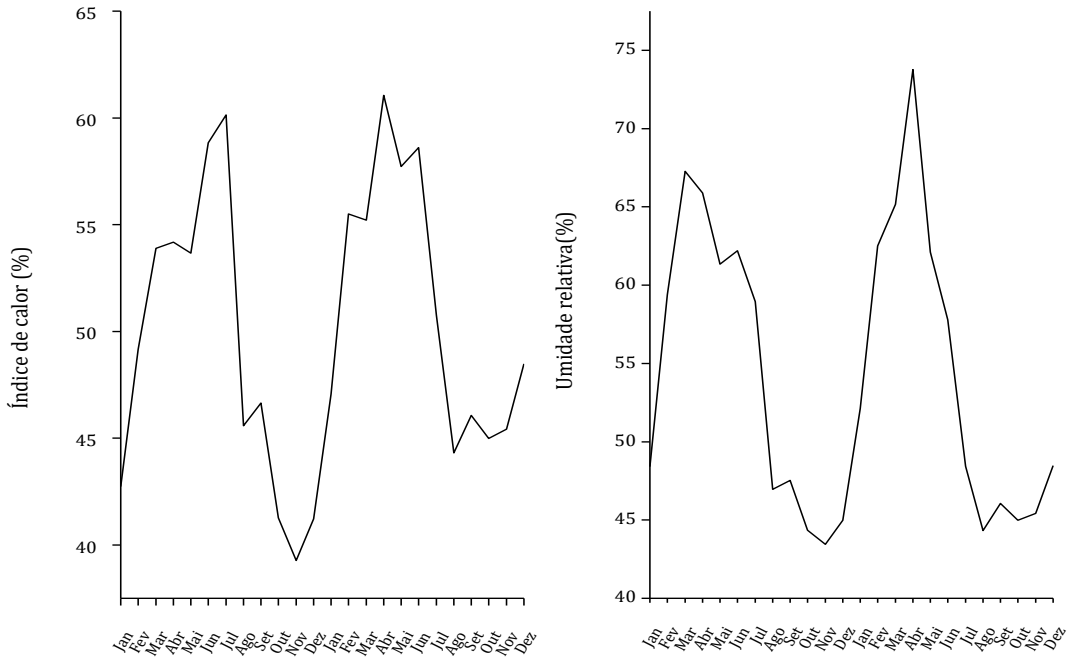


Through Graph 2, you can see that the monthly THI values in the period from 2017 to 2018 show the behavior of the values varying from 29.02 and 33.5°C when compared with Chart 3, classified as "extremely uncomfortable"

Observing Graph 2, it can be seen that URM values for the year 2018 obtained the highest value in April with 73.77%. In the averages of the months of the URM, it was possible to verify, using graph 2, that depending only on the relative humidity, the municipality did not reach the state of alert, since the lowest monthly average of relative humidity was greater than 43%, which occurred in November 2017.

According to the World Health Organization (WHO), the ideal level of humidity is between 40% and 70%, and when it is below 30% it is considered an alert situation and the damage to health becomes clearer.

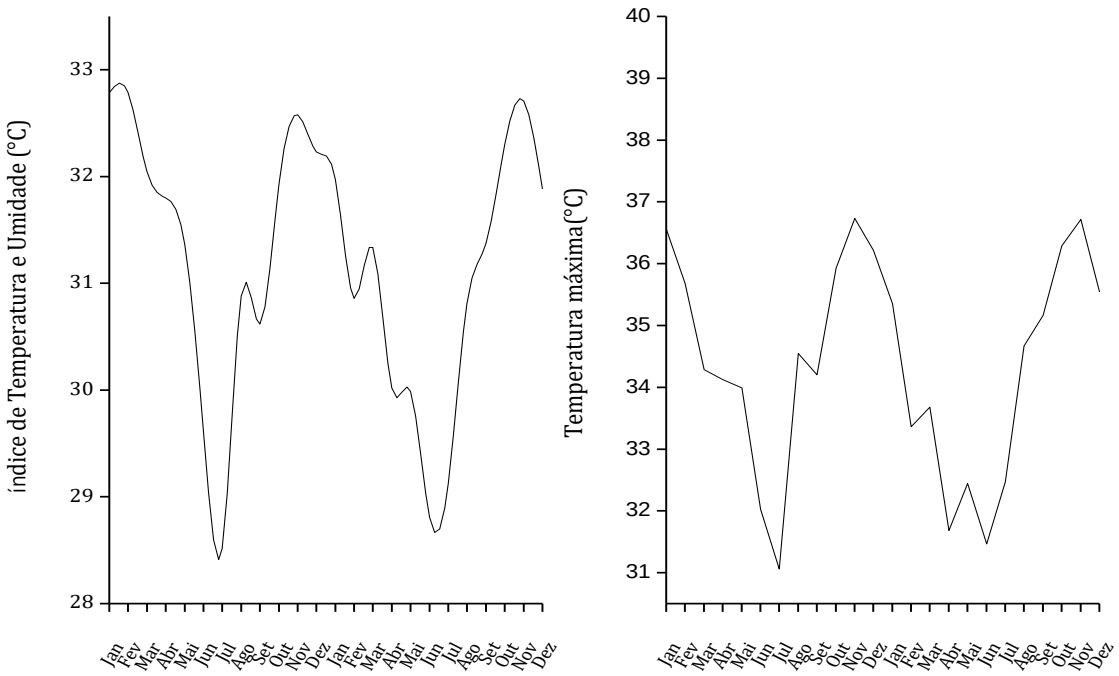
Graph 3. Heat Index (CI) and Mean Relative Humidity (URM) values of the monthly averages for the years 2017 to 2018 in the city of Patos, Paraíba.



Making a comparison between IC in relation, the average curve of Heat Index and URM is very similar to the curves (graph 3), due to Equation 1, showing that the relative humidity of the air is directly proportional to the Heat Index, it is important to bring the concept given by Cavalcante et. Al. (2017), where says that temperature is the inverse of relative humidity.

According to Cavalcante et al. (2017) the heat index is related to alert levels of various physiological symptoms, with a CI of less than 27°C, there is no risk; with a CI of 27 to 32°C, risk of attention; with IC from 32 to 41.1°C, be very careful; with IC from 41.1 to 54°C there is danger; with CI greater than 54°C there is extreme danger, with the possibility of heat stroke and stroke. Therefore, in all years of study, the values of these heat indices showed a poor quality of life. Therefore, the vegetation cover is one of the main mitigating elements of this problem and can also collaborate with thermal comfort, with an essential function in the quality of life of the population, acting in the softening of the temperature of the cities, decreasing and with that the Heat Index.

Graph 4. Values of the Temperature and Humidity Index (ITU) and maximum temperature (TMM) of the monthly averages of the years 2017 to 2018 in the city of Patos, Paraíba.

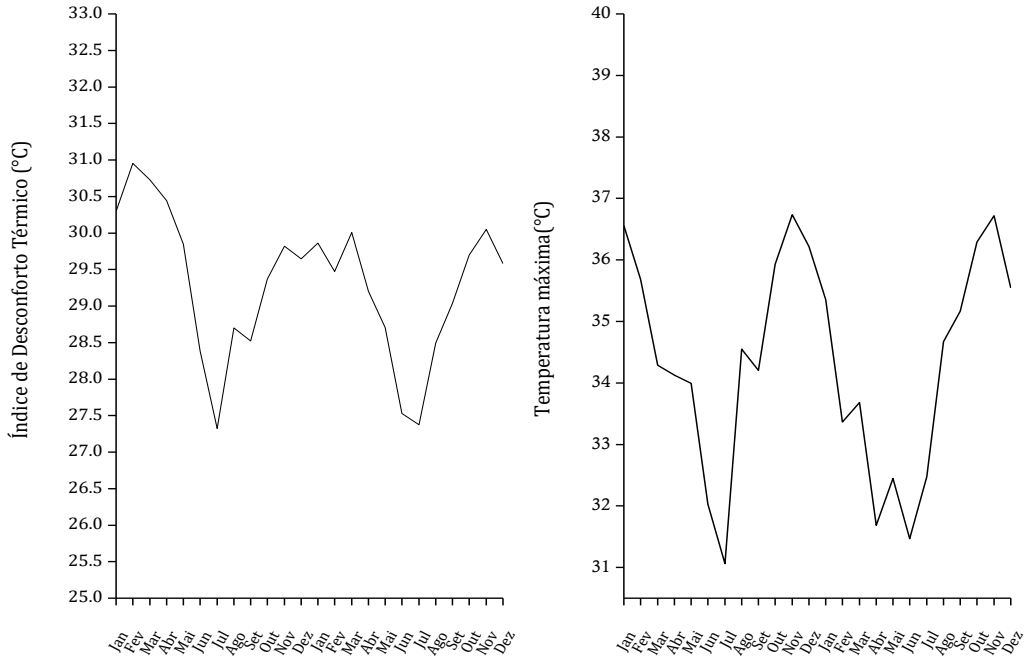


As can be seen (Graph 3), the relationship between temperature and the Temperature and Humidity Index (ITU) during the year 2017 to 2018.

It is seen that the lowest values of the averages of the maximum temperature months were recorded in 2017 (31.06°C) to 2018 (31.47°C), there was a difference of 0.41°C. In 2018, the highest values (Graph 3), found the MMR was in November 2017 and 2018 (36.73°C and 36.72°C), respectively.

The lowest THI value in 2017 was 29.02 °C in July. In 2018 the lowest value was 30.24°C in August. The highest value found for UTI in the period was 33.53°, as shown in Table 3. The values in the period are considered extremely dangerous to the health of the population in terms of quality of life in the municipality of Patos -PB.

Graph 5. Values of the Thermal Discomfort Index (RTI) and maximum temperature (TMM) average of the monthly data from 2017 to 2018 in the city of Patos, Paraíba.

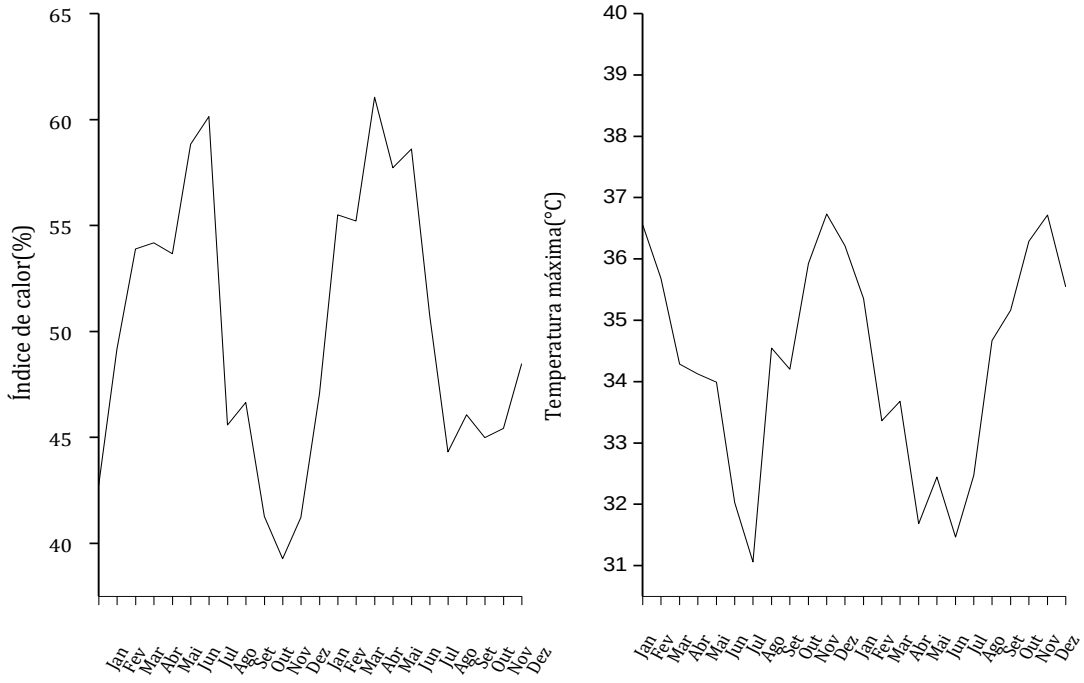


Through the data in Graph 5, during the entire period studied, the population of the municipality of Patos-PB was exposed to thermal "discomfort". The behavior of the curves demonstrates a relationship between the Thermal Discomfort Index and its temperature.

According to Santos et al. (2015), these are conditions of high temperatures, which can lead to an increase in the body's cellular metabolism, as well as the production of heat, so that the body begins to show symptoms such as intense sweating and changes in breathing and heart rate.

According to Silva et al. (2009), if the thermal discomfort index (RTI) was greater than or equal to 26.5 °C, it is already considered an uncomfortable level, and the lowest value obtained was 28.9 °C.

Graph 6. Heat Index (CI) and maximum temperature (TMM) values of the monthly averages from 2017 to 2018 in the city of Patos, Paraíba.



Observing Graph 6, it can be seen that the values, were determined by the relationship between the TMM and the heat index (CI), during the periods from 2017 to 2018. It is seen that the lowest value of the average of the month of TMM was recorded at 31.06°C (July 2017) and 31.47°C in June 2018. The annual average of 2017 (was 34.62°C), 2018 of 34.07°C and the average value over the range (2017 to 2018) was 34.34°C.

The thermal sensation values, registered through the Heat Index (CI) and presented (graph 6), point to an average above 45 °C for all years of study, as shown in table 1, denoting the dangerous level of alertness and the possibility of fatigue, drowsiness, exhaustion, and brain damage, if excessive exposure occurs by the population of the region. The behavior curves of the indices do not show a continuous pattern, with an increase in average maximum temperatures in the years of study of 34.34 °C and the heat index in the period of 53.67 °C.

The municipality of Patos-PB presented CI, TDI, and THI of 53.67°C, 30.52°C, and 31.38 °C, respectively. These values are considered of high magnitude and may be related to several health problems, being characterized as a thermally uncomfortable environment.

REFERENCES

Barbirato, gianna melo; de souza, léa cristina lucas; torres, simone carnaúba. **Clima e cidade: a abordagem climática como subsídio para estudos urbanos**. Ufal, 2007.

Carfan, a. C.; galvani, e.; nery, j. T. **O efeito do sombreamento no conforto térmico**. Estudo de caso: cidade de são paulo. Vi seminário latino americano de geografia física e ii seminário ibero americano de geografia física universidade de coimbra, 2010.

Cavalcante, f. M. S.; bruno, i.; figueredo, m. L. **Análise do índice de calor e desconforto térmico na cidade de caicó-rn**. N. 83, 2017.

Ibge. **Panorma da cidade de patos**. Disponível em:ttps://cidades.ibge.gov.br/brasil/cpb/patos/panorama. Acesso em: 01 jan. 2019.

Inmet. Dados históricos. Disponível em: http://www.inmet.gov.br/portal/index.php?r=bdmep/bdmep. Acesso em: 27 fev. 2019.

Leal, l. **A influência da vegetação no clima urbano da cidade de curitiba – pr. 2012. Tese (doutorado em engenharia florestal)** – curitiba: universidade federal do paraná.

Nóbrega, r. S.; lemos, t. V. Da s. **O microclima e o (des) conforto térmico em ambientes abertos na cidade do recife**. N. 1, p. 93–109, 2011.

Oms, organización mundial de la salud. **Actas oficiales de la oms**. Disponível em: http://www.who.int/library/collections/historical/es. Acesso em: 14 ago. 2019.

Queiroga, daniel queiroga et al. **Índice de calor e desconforto térmico humano nas condições de ambiente natural em patos,** pb, brasil. 2019.

Santos, j. B. Et. Al. **Análise temporal da sensação térmica nas cidades de patos e são gonçalo (sousa), paraíba, brasil**. Anais ii wiasb. Editora realize. 2015.

Santos, j. S.; silva, v. P. R.; araujo, l. E.; lima, e. R. V.; costa, a. D. L. **Análise das condições do conforto térmico em ambiente urbano: estudo de caso em *campus* universitário**. Revista brasileira de geografia física, v. 2, p. 336-353, 2011.

Silva, v.p.r. azevedo, p.v.; brito, r.s.; campos; j.h.b.c. (2009). **Evaluating the urban climate of a typically tropical city of northeastern brazil.** Environ monit assess. Doi 10.1007/s10661-008-0726-3.

Steadman, r.g. **the assessment of sultriness: part i: a temperature-humidity index based on human physiology and clothing science**. J. Appl. Meteor., 18: 861-884, 1979.

Thom, e.c. **the discomfort index**. Weatherwise, boston, v.12, n.1, p.57-60, 1959.